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UNDERSTANDING TUBERCULOSIS MORTALITY FLUCTUATION IN THE PHILIPPINES BY ARTIFICIAL INTELLIGENCE

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ABSTRACT

The Philippines is one of the countries with high tuberculosis (TB) mortality across the globe. This study investigates the trends of the TB mortality and morbidity incidence from 1998 to 2010 based on the surveillance data of the Department of Health. From the dataset, symbolic regression was used to forecast yearly morbidity cases of TB. Using the same analysis, a significant non-linear correlation between TB morbidity and TB mortality was revealed. Analyzing the equation, the trend component represented by the first two terms shows that the morbidity cases increases like a quadratic function. The correction factor, however, tells us that there are fluctuations around the trend curve because of the presence of the cosine terms. Following the equation generated through symbolic regression, in the next 15 years (2011–2025), there is an increasing number of TB morbidity cases considering the present TB Control Programs of the country. Mortality cases follow the same increasing trend but with evident fluctuations over the years. Therefore, without the presence of government and non-government-initiated TB prevention and control programs, there would be an increase in both TB morbidity and mortality cases in the Philippines. Conversely, the existence of such interventions will slow down the rise of TB mortality and morbidity. Full implementation of anti-TB programs is to be mandated to and must be adhered by all public and private healthcare institutions to help realize the vision of a TB-free Philippines.

Keywords: Tuberculosis, Mortality, Morbidity, Forecast, Symbolic Regression

INTRODUCTION

Tuberculosis (TB) is considered as a global burden which has affected over millions of people worldwide. World Health Organization Global Tuberculosis Report, 2016) . It has been identified that in 2016, Tuberculosis is one of the top 10 leading causes of death in the world even though it's curable and has been the focus of health programs over the past decades. Reported global data from the same agency revealed that 10.4 million people fell ill with TB, 1.7 million died from the disease (including 0.4 million among people with HIV) with over 95% of deaths occurring in low- and middle-income countries (World Health Organization, 2018).

In the Philippines, the National Tuberculosis Control Program (NTP) has a current estimated TB burden which accounts for mortality of 21 per 100 000 persons and incidence of 554 per 100 000 person (Department of Health, 2017). It remains to be one of the top ten (10) leading causes of morbidity and mortality in the country. In fact, the country is included in the list of the 30 highest TB-burden countries in the world with additional multidrug-resistant TB burden (Vianzon *et al.*, 2013).

In this article, the mortality and morbidity trends of tuberculosis in the Philippines are being investigated. Further, the study would like to see how morbidity affects the mortality of the same disease. By doing so, the number of TB mortality can be forecasted using the yearly TB morbidity cases as recorded. In addition, looking into the forecast would provide a glimpse of the impact of the present TB control programs in the country.

LITERATURE REVIEW

In order to measure the effectiveness of a particular treatment, two of the indicators analyzed are the morbidity and mortality rates of a disease. In the case of tuberculosis, it has been reported in 2016 by the World Health Organization (WHO) that there was a decline by 47% in mortality and 42% in prevalence between 1990 and 2015 globally. The statistics reflect the collaborative efforts of various organizations in reducing the incidence and prevalence of the said communicable disease (PhilCAT Convention, 2016).

In the Philippines, a study conducted by (Vianzon *et al.*, 2013) reported that from the year 2003 to 2011, the National TB Control Program has enlisted around 1 379 390 or eighty two percent (82%) of TB cases which are considered asymptomatic upon examination while there is around eighty five percent (85%) successful rating for annual treatment. Such performance trend could likely catapult the Philippines towards its target of reducing the country's present TB burden. However, in a prospective community-based survey in the Philippines conducted from May 2013 to July 2015, it was revealed that TB remains as an important health problem in the country despite the recently established diagnostics and adopted treatment strategy for Tuberculosis (Lopez, 2016).

The World Health Organization Stop TB Strategy ended by 2015 but evidences show that there is still no significant decline in the prevalence estimates for 2007 and 2016 in the Philippines (Program, 2017 . To address this persistent health concern, the Department of Health has established medium term goals with a vision of a TB free Philippines. The following are the aims of the agency: (a) decreasing the number of TB deaths by 50% from 14,000 to 7,000 and (b) decreasing TB incidence rate by 25% from 322/100,000 to 243/100,000 (Department of Health, 2017). In this context, the researchers are interested to see how the patterns of TB morbidity and TB mortality over the years (1998 to 2010). This will help in forecasting the number of future cases considering the TB programs currently implemented in Philippines. Subsequently, it may become one of the basis to restructure the TB control and prevention programs in the Philippines if deemed to be unfitting or ineffective in the next couple of years.

RESEARCH METHODOLOGY

The researchers utilized the symbolic regression. A type of regression analysis that searches the space of mathematical expressions to find the model that best fits a given data set both in terms of accuracy and simplicity. Through the process of Data Mining, the researcher extracted the information affecting the trends of the TB mortality and morbidity incidences from 1998 to 2010. The data searched were computed to calculate the mathematical expressions of accurate prediction equation for structural relationship of the data.

Conceptual Framework

The study rests on the idea that for communicable diseases, such as pulmonary TB (PTB), the present number of cases is a function of the immediate past numbers of TB cases recorded. In particular, if the immediate past number of TB cases is $\{X_t\text{-}1\}$, then the present number of TB cases $\{X_t\}$ represents the number of people infected by the previous number of TB cases plus or minus new TB cases (A). The model suggests that:

(A) Present Number of Cases = *(Portion of Individuals Infected by Past TB Patients) ± (New TB cases)*

In symbols:

(B) $X_t = f(X_t\text{-}1)$

We note that modelling for non-communicable diseases differ from equation (B) in that the present number of cases for non-communicable diseases does not depend upon the previous number of cases but grows as a function of time (t):

(C) Non-Communicable Diseases

$X_t = f(t)$

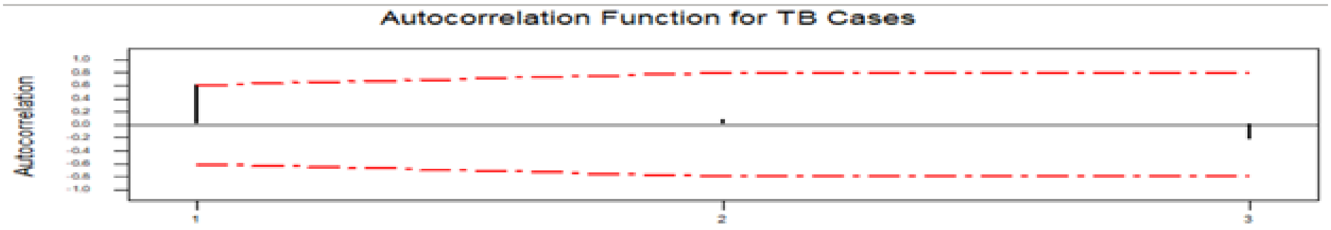
While there are other competing models for communicable diseases such as the

Susceptible → Infected → Recovered (SIR) model, equation (B) represents a much simpler and practical way to approximate the morbidity cases since it does not involve the concept of Stochastic processes.

The 13-year period (1998-2010) data for TB morbidity and TB mortality cases in the Philippines was extracted from the database of the Department of Health (DOH). Through auto-correlation, it was determined that the number of TB cases of the previous year influences the current cases of TB. Further, symbolic regression was utilized to treat the data and predict the future yearly cases of the disease. Lastly, to check the nonlinear relationship between TB morbidity and TB mortality, the data were again analyzed using symbolic regression.

RESULTS AND DISCUSSION

To forecast the future yearly cases of Tuberculosis, a 13-year data from 1998 to 2010 were processed utilizing Minitab Software version 12. Based on the *T*-values, the results show that the current cases are significantly influenced by the number of cases of the previous year (lag 1) based on the cut-off criterion of 1.96. The conceptual framework therefore, is supported by available evidence. This can be explained by the communicable nature of tuberculosis.



Lag	Corr	T	LBQ
1	0.60	2.17	5.89
2	0.08	0.21	5.99
3	-0.23	-0.64	7.06

Figure 1: Autocorrelation of PTB Morbidity

Symbolic regression was used to arrive at the formula: X = f (Xt-1) which indicates that the present TB cases of a particular year is influenced by the number of TB cases of the previous year.

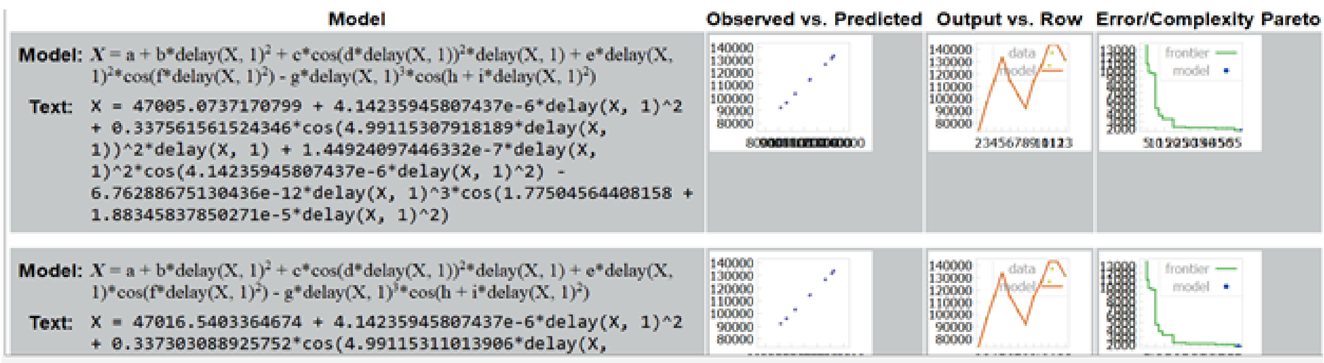


Figure 2: Best PTB Equation

The equation in the figure above shows the curve fitting which shows the best fit to forecast the future PTB cases. As such,

Equation (1)

$X = 47005 + 4.14e\text{-}6(X_{t-1})^2 + 0.34*\cos(4.99*(X_{t-1})^2*X_{t-1} + 1.44e\text{-}7*(X_{t-1})^2*\cos(4.14e\text{-}6*($
$6.76e\text{-}12*(X_{t-1})^3*\cos(1.77 + 1.88e\text{-}5*(X_{t-1})^2)$

Trend: $47005 + 4.14e\text{-}6(X_{t-1})^2$

Correction factor: $0.34*\cos(4.99*(X_{t-1})^2*X_{t-1} + 1.44e\text{-}7*(X_{t-1})^2*\cos(4.14e\text{-}6*(X_{t-1})^2 - 6.7$
$12*(X_{t-1})^3*\cos(1.77 + 1.88e\text{-}5*(X_{t-1})^2)$

1618.4385 MAE
100% converged

Equation (1) shows the prediction equation for the TB morbidity cases. The trend component represented by the first two terms, namely: **47005+0.00000414 $(X_t-_1)^2$**, shows that the morbidity cases increases like a quadratic function, i.e, faster than linear rate. The correction factor, however, tells us that there are high frequency waves or the "up" and "down" pulling movement because of the presence of the cosine terms. The quadratic trend for TB can be explained by the communicable nature of TB and the fact that in the Philippines, close family ties, poor sanitation and unfavorable living conditions tend to facilitate transmission of the disease.

The correction factor on the other hand, can be explained by the various TB interventions or DOH intervention programs like TB-DOTS and NTP.

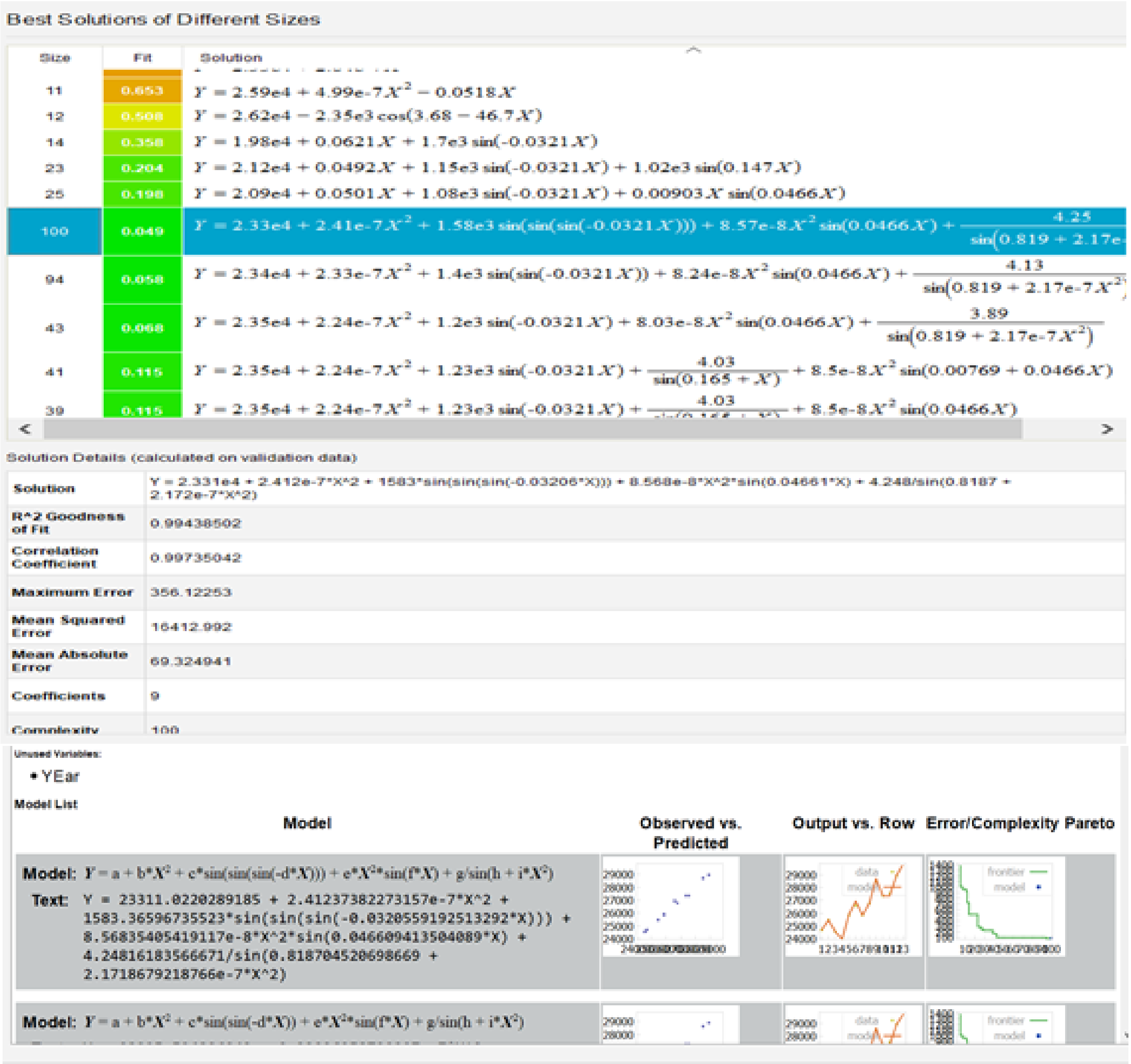


Figure 3: Relationship between Morbidity and Mortality of Tuberculosis

Figure 3 shows the solution used for TB Morbidity and Mortality correlation with the Mean Absolute Error of 69.32.

Equation (2)

Y =23311+ 2.41e-7*X^2 + 1583.36*sin(sin(sin(0.03*X))) + 8.56e-8*X^2*sin(0.0... 4.24/sin(0.81+ 2.17e-7*X^2)

General Pattern: 23311 + 2.41e-7*X^2

Correction Factor: 1583.36*sin(sin(sin(0.03*X))) + 8.56e-8*X^2*sin(0.04*X) + 4.24/sin(0.81+2.17e-7*X^2)

MAE = 69 (lowest)
Percentage coverage = 100%

Equation (2) shows the relationship between TB mortality cases and TB morbidity cases. The first two terms show the general pattern of relationship, namely 23,311 + 0.000000241 (morbidity) 2, indicating that the mortality is a fraction of the square of morbidity in general. However, the correction factor involves sine terms implying that the predicted mortality will go up or down the general trend.

In relation to the context of TB in the Philippines, although a significant progress has been made to eliminate TB as a public health burden, it remains one of the leading causes of morbidity and mortality. WHO reported that there are about 3 million estimation of cases which were missed each year – undiagnosed, treated or reported to National TB Programs (World Health Organization, 2016). Additionally, the rapid emergence of multi-drug resistant TB (MDR-TB) has the potential of reversing the two decades of progress mitigating the impact of TB (Department of Health, 2017).

Using the equation for predicting future number of cases of TB, the following data were gathered and placed in a graph.

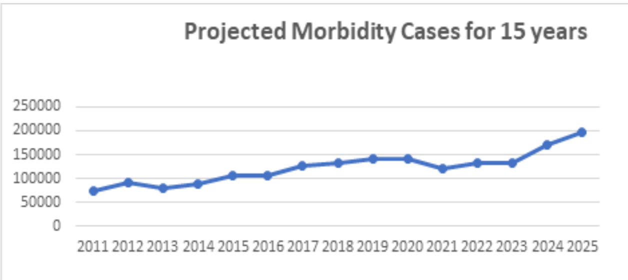


Figure 4: Forecasted Morbidity Cases from 2011 to 2025

Figure 4 shows a general increase in the number of TB cases in the next 15 years. This tells us that if the current National TB Control Program be used throughout these years, then there will be increasing incidence of TB in the Philippines.

After running the trend for morbidity and mortality cases using symbolic regression, the following data below showed the number of forecasted TB mortality in the next 15 years.

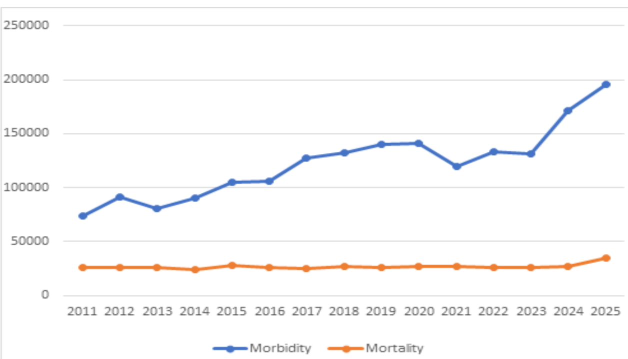


Figure 5: Trend of forecasted Mortality cases for thenext 15 years in comparison to the forecasted morbidity cases

Figure 5: Trend of forecasted Mortality cases for thenext 15 years in comparison to the forecasted morbidity cases

Figure 5 shows that there is an increasing number of TB mortality cases in relation to the morbidity cases in the next 15 years (2011-2025). Roughly, in the year 2025, morbidity cases of 195,000 will have a mortality case of 35,000. The observed fluctuations in the graph can be attributed to the number of possible relapses of TB cases and new case notifications. The data above implies that with the projected number of mortality case, the NTP implementation in the Philippines should be strengthened, improved or restructured in order to be more responsive to the goals set by the Department of Health. The same agency targets to decrease the number of TB deaths by 50% and TB incidence by 25% in the year 2020.

CONCLUSION

The TB morbidity cases increases like a quadratic function, faster than the linear rate. This behavior could be attributed to the communicable nature of TB and other factors affecting the rapid transmission of the disease specially in the Philippine setting. Such factors may include, urban poverty, poor living conditions (living in slum areas), poor sanitation practices and families living closely to one another. However, the correction factor shows the "up" and "down" pulling movement due to the presence of the cosine terms. This phenomenon can be explained by the various government and non-government TB prevention and control measures that are presently implemented in the country (i.e. TB – Directly Observed Treatment Short-Course (TB-DOTS), and National TB Control Program).

The relationship between TB morbidity and TB mortality reveals a general pattern which indicates that the TB mortality is a fraction of the square of morbidity. Meaning, the predicted TB mortality is just a portion of the total morbidity cases. On the other hand, the correction factor involves sine terms which implies that the predicted mortality will exhibit an "up" or "down" pulling movement with respect to the general trend. In the context of TB in the Philippines, this pattern may be represented by various factors leading to mismanagement of TB (i.e. failure to follow up due to medication side effects or fear of side effects, poor information support system from health care personnel, and limited ways and means of reaching the health facility).

Therefore, without the presence of government and non-government-initiated TB Prevention and Control Programs, there would be an increase in both TB morbidity and mortality cases. Conversely, the existence of these programs will slow down the rise of TB mortality and morbidity. In relation to the forecasted TB mortality cases in the Philippines, it is but fitting that the government should restructure or improve the currently implemented TB control and prevention programs to address the barriers in achieving a decreased TB burden. Further, the strict implementation of these anti-TB programs is to be mandated to and adhered by all public and private healthcare institutions to help realize the vision of a TB-free Philippines.

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